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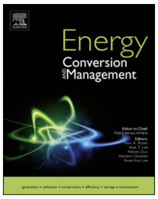

Techno-economic comparison of the levelised cost of electricity generation from solar PV and battery storage with solar PV and combustion of bio-crude using fast pyrolysis of biomass

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ABSTRACT

The strong growth of intermittent electricity generation from solar PV and wind is leading to a greater need for energy storage at grid scale. In this work a techno-economic model has been constructed to calculate the levelised cost of electricity for two systems that can meet an arbitrary energy demand curve: (1) solar PV and battery storage and (2) solar PV with combustion of bio-crude and bio-gas from biomass. The analysis is performed for conditions prevalent in Queensland, Australia where over a gigawatt of new solar PV capacity is being constructed in 2018. The battery storage assumes lithium-ion batteries and costs derived from the recently constructed Hornsdale Power Reserve in South Australia. A variable energy demand curve is assumed in the work. The model shows that the parameters with the most impact on the LCOE for the solar PV and battery system are the solar yield, and total installed costs of the battery and solar PV unit. Assuming, battery costs of 750 AUD/kWh, solar PV costs of 1.6 AUD/W and a project capacity of 240 MWh/d, the LCOE of the solar PV and battery system was calculated to be 170 AUD/MWh. Using total installed costs forecast for the near future, the LCOE is expected to be in the range 150–185 AUD/W for the variable energy demand curve, and over 200 AUD/MWh if a constant supply of power is required. The parameters with the most impact on the LCOE for the solar PV and bio-crude system are the solar yield and total installed cost of the biomass pyrolysis and bio-crude combustion unit. For a 240 MWh/d project scale with variable energy demand, the LCOE for the solar PV and bio-crude system is estimated to be 116 AUD/MWh. Variations in feedstock cost and project scale showed that the LCOE is in the range of 104–125 AUD/MWh. The main conclusion from this work, is that integration of solar PV and the production and combustion of bio-crude and bio-gas using fast pyrolysis of biomass, leads to competitively priced dispatchable renewable energy that is forecast to be cheaper than using solar PV and batteries for the foreseeable future. It has also been found that the combination of solar PV and bio-crude combustion leads to lower LCOEs than using bioenergy alone, due to the rapidly decreasing costs of large scale solar PV. While the solar PV and bio-crude system analysed in this work will likely be a niche solution, in areas with substantial biomass resources, it offers a credible starting point for the development of larger scale bioenergy value chains, with the longer term goal of converting lignocellulosic biomass materials into renewable transportation fuels and chemicals.

1. Introduction

Solar PV is now an established technology for power generation in both small scale residential and large scale utility projects [1]. In Australia, solar PV from small, medium and large installations accounts for about 3.2% of total energy supply. As at the end of 2016, there were over 5480 MW of small (< 100 kW) and over 200 MW of medium scale (< 5 MW) solar projects in operation [1]. Large scale solar PV installations are increasing rapidly due to decreases in panel and installation costs. As of May 2018, a total of 2756 MW of new capacity in utility scale solar projects is under construction, committed or already completed in Australia in 2018 [2]. A major challenge to increased penetration of intermittent renewables is the development of cost effective energy storage. In many locations the combustion of natural gas is being used to manage the intermittency of renewables, with natural gas often setting the price of electricity on the network [3]. Global energy storage capacity is dominated by pumped-hydroelectric projects, however hydro resources are limited and new hydro-electric projects have very long project delivery timelines. Energy storage using electro-chemical batteries is developing quickly, aided by the

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Nomenclature

List of Acronyms

BOP	Balance of Plant
BTG	Biomass Technology Group
DCF	Discounted Cash Flow
IRENA	International Renewable Energy Agency
LCOE	Levelised Cost of Electricity
LHV	Lower Heating Value
LI-ION	Lithium Ion
PB	Lead
PV	Photovoltaic
RTP	Rapid Thermal Processing
TIC	Total Installed Cost
VRF	Vanadium Redox Flow

development of electric vehicles where battery performance and cost are critical. Recently, the world's largest utility scale battery was built in South Australia by Neoen using Tesla supplied batteries with a capacity of 129 MWh of energy storage [4]. Energy storage techniques such as flywheels and compressed air are also being investigated, with some projects in operation.

Other renewable energy resources such as bioenergy materials, especially biomass, wood waste and agricultural wastes are readily available in various regions and in many cases they are not being fully harvested or collected at present. Bioenergy projects currently deliver about 8.6% of the clean energy generated in Australia and 1.5% of total energy [1]. A variety of conversion technologies can be applied to biomass resources, such as combustion, gasification and pyrolysis [5,6], however generally all thermochemical processes work best when operating at a constant feed rate. When considering the application of energy storage, pyrolysis has the advantage of high flexibility as the pyrolysis unit can produce a liquid fuel (bio-crude) at a constant rate, that can be stored and used as and when required. Bio-crudes may also be upgraded into transportation fuels that can play a role in reducing the greenhouse gas emissions of the transport sector, especially in aviation, marine and heavy haulage for which alternatives such as batteries or hydrogen may not be well suited or require substantial and costly changes to infrastructure and vehicle fleets [7–10].

In this paper, a techno-economic comparison is made of producing dispatchable electricity from (1) solar PV with battery storage and (2) solar PV with combustion of bio-crude produced from fast pyrolysis of biomass. While the production and combustion of bio-crude to augment intermittent renewables is likely to be a niche application, in regional areas with substantial agricultural wastes and woody biomass resources, this solution may offer many advantages in adding value to the regional agricultural sector and in helping to develop large scale bioenergy value chains to fuels and chemicals in the longer term. The intermediate production of bio-crude from biomass enables the chemical energy to be stored and then used in engines or turbines to produce electricity when required to supplement the intermittent nature of solar PV or wind. As found in this analysis, conditions exist where the levelised cost of electricity (LCOE) from the combination of solar PV and bio-crude production are lower than those forecast for solar PV with battery storage.

2. Daily energy demand

The daily energy demand is a function which specifies the electrical demand for the plant for each hour in the day. The daily energy demand function is an input. In this work, the daily energy demand is assumed to be the average for each day of the year. This assumption is satisfactory so long as the average peak is representative of the actual peak demand that will be catered for. At one extreme, a short duration of demand at peak times would represent a conventional peaking power plant. At another extreme, a completely uniform daily energy demand function would represent a conventional base load power plant. In this work two daily energy demand curves are simulated – one with a typical profile of variable energy demand and another with a constant energy demand throughout the day. Fig. 1 shows the energy demand curves used in the work, both of which have a total energy demand of 240 MWh/d. Most of the analyses are conducted assuming the variable

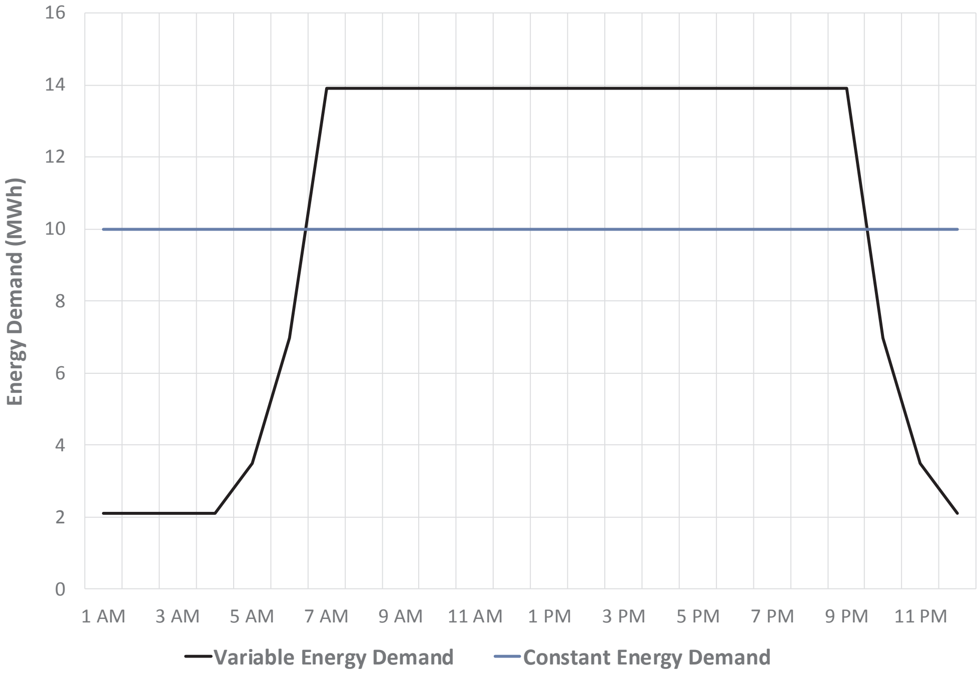

Fig. 1. Daily electricity energy demand curves: variable and constant energy demand.